Sprague Bridge (Ninth Street Bridge)
Over the Yellow River
Towns of Armenia and Necedah
Juneau County
Wisconsin

HAER No. WI-57

HAER
WIS,
29-ARM,
1-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORICAL AMERICAN ENGINEERING RECORD
National Park Service
Rocky Mountain Regional Office
Department of the Interior
P.O. Box 25287
Denver, Colorado 80225

HAER
WIS,
29-ARM,
1-

HISTORIC AMERICAN ENGINEERING RECORD

Sprague Bridge (9th Street Bridge)

HAER No. WI-57

Location: Spanning the Yellow River, carrying traffic from 9th Street East, between the towns of Armenia and Necedah, Juneau County, Wisconsin.

UTM: 15.731250.4891476
Quad: New Miner

Date of Construction: 1913

Bridge Fabricator: The Elkhart Bridge and Iron Company
Elkhart, Indiana

Present Owner: Towns of Armenia and Necedah

Present Use: Vehicular and Pedestrian Traffic

Significance: The Sprague bridge is one of the state's finest remaining, unaltered, examples of a Pratt half-hip pony truss. The two span structure is one of the earliest bridges constructed under the auspices of the State Highway Commission. The bridge fabricator, The Elkhart Bridge and Iron Company of Indiana and the local contractor, Willis E. Gifford were prolific independent bridge builders in Wisconsin.

Historian: Edwin G. Cordes
For Mead and Hunt Inc.
Madison, Wisconsin
March, 1989

The Sprague Bridge is a two span, pinned, steel, Pratt half-hip pony truss bridge which carries Ninth Street East across the Yellow River between Necedah and Armenia townships. It was built by the Elkhart Bridge and Iron Company through its agent, Willis E. Gifford, in 1913. With the pin connections and steel tube abutments, the Sprague Bridge is representative of a rural, turn-of-the-century wagon bridge. It was most likely built with a minimum of power tools, and is one of the last pin connected Pratt highway bridges built in the state.[1] The State Highway Commission, formally established in 1911, two years before the Sprague Bridge was constructed, advocated riveted Warren truss bridges and concrete abutments for this type of crossing.[2]

Each of the two spans has a length of 58'8". The overall structure length is 121'7". The roadway width is 15' and the web height is 5'4". The bridge superstructure utilizes "built-up" sections composed of various sized angle irons and channels. The bridge deck is composed of bituminous material and is supported by a corrugated metal deck and rolled I-beam floor beams and stringers. The span bears on metal capped steel tubes surrounded by steel diaphragm retaining walls at both the abutments and central pier. This type of a steel abutment represents a very late use of the technology. Standard roller type expansion bearings can be found at the retaining wall connections of both spans.

The basic Pratt truss design was patented by Thomas and Caleb Pratt in 1844 as a combination wood and iron bridge. The design soon evolved into an all iron or steel configuration. As an all metal bridge, the design became extremely popular because of its ease of erection and its sparse use of materials. The oldest existing truss bridge in Wisconsin, the 1877 White River Bridge in Burlington, is a Pratt.[3] The Pratt truss configuration places the diagonal members in tension and the vertical members in compression, except for the hip verticals which run from the inclined endposts and top chord connections and are in tension. A Pratt Half-hip bridge, like the Sprague example, does not have a hip vertical member.

Bridge plates attached to the outside inclined endposts identify The Elkhart Bridge and Iron Company, Elkhart Indiana as the builder and W.E. Gifford of Madison WI as the agent. A second set of bridge plates also recognizes the Armenia Town Supervisors as well as the Juneau County Supervisors' committee of oversight for their involvement in the project.[4]

An interesting feature of the bridge is the lower chord members. The exterior panels on each span utilize double tied angle irons while the two interior panels use looped eye-bars. The first technique is representative of 20th century technology, while the looped eye-bars represent earlier 19th century technology.

The Sprague Bridge crosses the Yellow River which flows generally from north to south eventually joining the Pentenwell Flowage and the Wisconsin River to the southeast. The surrounding area is primarily wooded wetland and floodplain. The closest town is Sprague, located one mile northwest of the bridge. Established as a post office along the Chicago, Milwaukee and St. Paul Railroad around 1909, the town is located nine miles north of Necedah. Census record show that Sprague has 75 residents in 1913 and 100 in 1919.[5]

Willis E. Gifford

A plate attached to the Sprague bridge identifies the involvement of Willis E. Gifford in the construction of the span. As one of almost 100 small independent bridge builders in the state during this period, Gifford is significant for a number of reasons. His success, which continued for over twenty years, runs counter to the short-lived professions of most of the other builders. Perhaps more is known of Gifford than any other builder through a personal photo album and scrap book as well as written reports of his work. As an agent for the Elkhart Bridge and Iron Company for almost a quarter of a century, Willis Gifford was responsible for the construction of numerous bridges throughout the upper midwest, more specifically Wisconsin. He was representative of small independent bridge contractors who operated throughout the state during the period from 1870 to 1930. Perhaps more is known about Gifford's career than any other small bridge builder / agent thus making him an important individual in the history of Wisconsin bridge building.

The thirty years following 1900 saw radical changes occur in the process of bridge construction and fabrication. Like the steel industry in general, the bridge building industry began to consolidate itself into a number of large companies such as the American Bridge Company, near Chicago. By the 1920's these larger companies virtually controlled the marketplace, making bridge fabrication and erection by small entrepreneurs difficult. Gifford business, as an exception to the rule, continued to operate until the late 1920's.

Another factor contributing to the decline of the smaller fabricating and erection firms was the establishment of the State Highway Commission in 1911. this organization which will be discussed in more detail later, became responsible for the development of a unified state highway network. The duties included the development of standardized bridge plans. This standardization of construction gave larger fabrication firms an advantage by allowing them to easily produce bridge according to set designs more cheaply than the smaller more individualized firms. Despite these difficulties, Gifford's business continued to be somewhat profitable until at least 1929, a point at which his bridge contract work tapered off possible due to the Depression.

Willis E. Gifford was born in 1867 in New York City. After marrying and moving to Michigan, he arrived in Madison about 1900. Gifford's early work in the area included the sale of road graders and other machinery throughout the state.[6] A photo album listing bridges he was involved with shows that Gifford was acting as an agent for the Elkhart Bridge and Iron Company, well before he officially lists his occupation as bridge contractor and agent, in 1916.[7] Before this time, Gifford's occupation is listed only as travelling salesman. Madison City directories continued to list Gifford as an agent for Elkhart Bridge and Iron until 1931.

According to the builder's son, Willis E. Gifford Jr., his father was rarely involved in the actual construction of the bridges he contracted for. Gifford's role included submitting bids, attending the lettings and arranging for the contracts. Once he had received a contract he notified Elkhart Bridge and Iron Co. to begin fabrication and hired a job foreman. Foremen often involved in Gifford's contracts included Ed Rudd, George Sarbarker, or H.C. "Duff" Fagan. The later may have worked for Elkhart Bridge and Iron elsewhere. The foremen then hired the construction crews and were in-charge of the actual erection.[8]

Most of Gifford's early bridges were pony trusses, either pin connected Pratts or riveted Warrens. The longest known bridge that Gifford contracted for was a 150 foot Pratt overhead truss over the Peshtigo River in Marinette County, Wisconsin.[9] Gifford did arrange for repair work on larger structures. He also constructed numerous smaller I-beam and concrete girder bridges throughout the state. It is not known if the Elkhart Bridge and Iron Company was involved in the fabrication of these projects.[10]

Gifford's son noted that although his father was an aggressive and resourceful agent, he never made much money as a bridge contractor. Gifford's business was most prolific in the years before World War I when he was involved in as many as 70 contracts a year. Although the Elkhart Bridge and Iron Company survived at least the early years of the depression, Gifford's involvement in bridge building ended around 1930. He died in Madison in the 1940's.[11]

The Elkhart Bridge and Iron Company

The Elkhart Bridge and Iron Company was incorporated in Indiana in November, 1901. This date was late in the third phase of industrial development of Indiana's metal bridge building history, a period which has been termed an age of "industrial expansion" for these companies. This period of expansion lasted roughly from 1889-1902, and was marked by a change from experimentation in design to a focus on efficient fabrication. Elkhart Bridge and Iron was one of eight important bridge companies formed in Indiana during this period.[12]

The two principle founders of the Elkhart Bridge Company were Frank Brumbaugh and John Fieldhouse. Brumbaugh was formally an agent for the Bellefontaine Bridge Company of Ohio. Fieldhouse, a local Elkhart industrialist joined the partnership to boost the local economy. The company did not prosper until it was reorganized in 1906 as the Elkhart Bridge and Iron Company. By 1910, the company employed 125 people and earned $40,000.00 annually. The company's influence exceeded the boundaries of Indiana as they were known to have built bridges in Montana as well as Wisconsin.[13]

Elkhart Bridge and Iron Co. used the method of shop erection and disassembly of its bridges before shipping them to the site. This method, which varies from the more modern template system would have made Gifford's role more tenable since he was familiar with the company's construction processes.[14] Elkhart prided itself in the ornamental details of its bridge designs, but the remaining Wisconsin examples do not display much ornamentation. After the company's re-organization, Elkhart Bridge and Iron began to diversify, and its business began to include the manufacture of steel for building construction.[15]

Both the Elkhart Bridge and Iron Company and Willis Gifford's involvement with them is significant in the history of Wisconsin bridge building because their prosperity occurred as the industry was radically changing direction. Shortly after the turn of the century, the American Bridge Company was formed by "an immense merger of virtually all of the national bridge fabricators of the time", including the Milwaukee Bridge and Iron Company. According to one historian, the creation of the American Bridge Company radically changed the complexion of the entire industry.[16] In this period of huge mergers and standardization of design and fabrication it became increasingly difficult for an independent bridge manufacturer to continue to prosper. The Wisconsin Historic Bridge Advisory Committee has identified the Elkhart Bridge and Iron Company as a "known prolific out-of-state builder", the second highest ranking accorded to bridge companies on its rating scale.[17]

Design and Engineering

There are three essential aspects of a truss. First, a truss is a combination of relatively small members which are "framed or joined...to act as a beam".[18] Second, each component member is subjected only to tension or compression. (Tensile forces tend to stretch or elongate a member while compressive forces tend to push or compress a member.) Third, the component members of the truss are configured in triangles because "the triangle is the only geometrical figure in which the form is changed only by changing the lengths of the sides."[19] In other words, the triangle remains rigid until the forces applied distort or break the materials used in the components.[20]

A truss bridge consists of two trusses, each with a top chord, bottom chord, and endposts. The space enclosed by these members is called the web. The web members reinforce the truss. The particular arrangement of the web members was the subject of much study in the mid and late nineteenth century, and different names were given to trusses with different web configurations. the two most popular types of trusses in Wisconsin were the Pratt and the Warren.

Truss bridges are generally divided into three categories: pony or low trusses, overhead or through trusses, and deck trusses.[21] Both pony and overhead trusses carry the traffic between the trusses and the roadway is at or near the bottom chord. A deck truss carries the roadway at or near the top chord; thus, the roadway is on top of the trusses.

<u>Materials</u>

The relative merits of cast versus wrought iron bridge building were still being debated in the late 19th century, when the first surge of truss bridge building began in Wisconsin. Because cast iron is so brittle, it is subject to sudden and dramatic failure. Thus it was "an unsatisfactory material for bridges, and quite a number of failures occurred."[22] Shunned for a time in the United States in the 1850's, cast iron bridges made a comeback and then only "gradually but stubbornly," fell out of favor.[23] As late as 1870, one bridge engineer wrote that "the rigidity of cast iron is the very quality needed in a compression member." Moreover, as the quality of casting in the United States was excellent, "nothing can be found that will compare with cast iron for resisting strains of compression either in reliability or cost."[24]

Before the issue of cast versus wrought iron had been completely resolved, a new material entered the picture: steel. Steel was not a newly discovered material, of course, but high cost and small output had limited its use mainly to the manufacture of tools. The Bessemer and Siemens-Martin processes reduced the costs and greatly improved the quantity of structural steel available.[25] Steel was used for special purposes and special bridges beginning with the Eads Bridge in St. Louis in 1874. From the late 1880's to the early 1890's structural shapes (beams and columns) were rolled in both wrought iron and steel by the major manufacturers. The quantities and quality of steel remained controversial until the turn of the century, and engineers continued to debate the relative merits of the two metals.[26] Nevertheless, steel was the predominant if not the exclusive structural materials for bridges by the mid 1890's. Although some bridge building companies continued to advertise bridges built of either metal as late as 1900, after 1892 wrought iron structural shapes were no longer being produced.[27]

In the 20th century, the continued development of steel focused on alloys. Waddell devoted an entire chapter to alloy steels in his 1916 textbook and its 1921 sequel.[28] By 1921, one English engineer indicated that developments since the turn of the century had made both the "mild" steel of the 1890's and wrought iron old fashioned. Both the engineer and the metallurgist developed an increasingly sophisticated understanding of the variations which resulted from changes in the chemical composition, heat treatment, macrostructure and microstructure.[29] Because the major advantage of alloy steels lay in very long span bridges and welded connections, the latter feature not becoming common until after World War II, it is assumed that metallurgical developments were not a major concern for bridge engineers designing modest rural bridges such as the ones which predominate the current existing sample in Wisconsin.[30]

Historical Context

On Wisconsin highways, the predominance of metal truss bridges for crossings of all lengths seems to have lasted from about 1890 to 1910. Trusses remained an important bridge type in the state until the advent of World War II, but after 1910, most short crossings (less than 35 feet) employed girder, beam or slab spans of steel and/or concrete. The Wisconsin State Highway Commission (SHC), established in 1911 to improve the quality of road and bridge construction in the state, was particularly enthusiastic about using concrete for culverts and small bridges.[31]

The "bowstring" truss may have been the state's first, common, all metal truss configuration. Nationwide, thousands were apparently built, but the popularity of this design in Wisconsin is difficult to determine.[32] Although records of a number of them exist, none remain on Wisconsin Highways. Seven are preserved in parks and wildlife refuges.[33]

The two truss designs that came to dominate highway bridge construction by the late nineteenth century were the Warren and the Pratt. The Warren truss was patented by two British engineers in

1840. In this design, the vertical members handle only nominal stress, while the diagonals serve as both tension and compression members. The vertical members, like the diagonals, were usually paired angles, but of smaller dimension In Wisconsin, Warren trusses are by far the most common form of highway truss, having been promoted by the SHC after 1911. Of the approximately 450 Warren trusses remaining in the state in 1980, over four-fifths were riveted pony trusses built according to SHC plans.[34]

The Pratt truss, patented by Caleb and Thomas Pratt in 1844, features vertical compression members and diagonal tension members. During the 1870's, an important variation of the Pratt design was introduced for long-span bridges. Because the depth of truss required in the center of a bridge is greater than at the abutments, a considerable amount of material can be saved on a long span structure by "bending" the top chord into a polygonal configuration known as a Parker truss. If the top chord has exactly five sides, the bridge by convention, is called a Camelback truss. The addition of substruts and/or subties makes a Pratt into a Baltimore and a Parker into a Pennsylvania.[35]

The development of the Pratt and its variations was influenced by a debate over the merits of pin connections versus riveted connections for main truss members. Proponents of riveted bridges usually cited the advantages of increased structural rigidity and the reduction of damaging vibrations. In pin connected bridges, vibrations caused the pin to grind on the eye-bar, thus enlarging the pin hole. Advocates of pin connected bridges, on the other hand, emphasized the theoretically correct distribution of stresses and the reduced amount of metal required. They also criticized the difficulty of ensuring that a riveted joint was properly fabricated, especially in the field. The pin-connected bridge, they argued, was the reason why Americans surpassed the rest of the world in bridge building.[36]

The issue of pin versus riveted connections was complicated by practical factors, including machinery, tools, and power sources, both in the shop and in the field. The debate also was easily sidetracked by tangential issues, as, for example, when some commentators denied that the pin <u>per se</u> was the most important feature of "characteristically American" bridgework. In addition, both connection types came to incorporate features that were not an intrinsic part of the design. Many early riveted spans, for example, used the lattice girder (or multiple triangulation) design, which was clearly excessive in material, while many pin-connected bridges were dangerously light, particularly in their details. Thus, a fair comparison between the two systems was not always made.[37]

According to J.A.L. Waddell, the controversy raged in engineering circles for a dozen years around the turn of the century. No dramatic resolution of the issue occurred, but "time and steady development of the real science of bridge designing" gradually changed minds. Significant changes in riveting technology also altered the terms of the debate.[38] A compromise of sorts was finally reached, resulting in the adoption of the best features of each design. Riveted bridges were designed with less duplication of members and pin-connected bridges were still accepted for long span highway bridges.[39]

In Wisconsin, SHC officials clearly favored riveted construction from an early date. Consequently, the distinction between pin connections and riveted connections establishes an important sub-category boundary, separating the era of state planned bridges from the preceding period in which bridge companies were largely responsible for bridge design. As early as 1908, state engineers advocated the use of riveted pony trusses for short-span bridges.[40] When the SHC was formally established in 1911, the riveted Warren became the state's standard pony design. In that year, the SHC also drafted a standard plan for riveted, overhead, Pratt trusses, and by 1914, the agency had adopted riveted construction for all overhead Pratt variations. As SHC engineer A.R. Hirst wrote in 1913, "very seldom do we use a pin-connected truss...".[41]

In the mid-1930's, the SHC seems to have developed a preference for overhead Warren trusses for long span bridges, although some overhead Pratts continued to be built. Riveting remained dominant in bridge building until well after World War II. as late as 1931, the construction specifications of the American Association of State Highway Officials (AASHO) stated, "Welding of steel shall not be done except to remedy minor defects and then only with the approval of the engineer." As with other innovations, the full potential of welded bridges was not immediately recognized. Shortly thereafter, riveting rapidly disappeared, replaced by welding and high strength bolts.[42]

The Wisconsin State Highway Commission (SHC)

The involvement of local governments in bridge repair, replacement, and construction projects was the subject of numerous laws in the late 19th century. With the "Good Roads Movement" of the late 1890's and early 1900's, a specific set of proposals were put forth for greater involvement by the State government in promoting good quality bridges.[43]

In 1907, the wisconsin state legislature established a Highway Division within the Wisconsin Geological and Natural History Survey to conduct experiments in road design and to advise local governments about specific projects. The Highway Division began to develop an entire set of standardized bridge plans. Town governments, traditionally reluctant to hire an independent engineer to assist in bridge building, could now avail themselves of free engineering counsel from the state. At the same time, the legislature required counties to make a commitment to professional oversight and increased funding by appointing "a competent engineer or experienced road builder" to serve as County Highway Commissioner and by levying a tax of not less than one-fourth nor more than two mills on the assessed valuation of all county property for the county road and bridge fund.[44]

In 1908, Wisconsin voters removed the greatest obstacle to creating a progressive state-wide system of bridge and highway construction. In that year, by a three-to-one margin, the eliminated the state's constitutional prohibition against direct state aid to transportation projects. When the legislature made its first appropriation for highway improvements in 1911, it also transformed the Highway Division of the Geological Survey into an autonomous State Highway Commission (SHC), which was given the responsibility of overseeing the expenditure of state funds for the development of a state highway network.[45]

Like the former Highway Division, the SHC emphasized the use of standardized plans for various types of bridges and culverts.[46] The first set of standardized truss plans encompassed spans ranging from 36 to 128 feet, generally in five-foot increments. All but one had a sixteen-foot roadway. Revised several times by the 1920's, these plans gradually provided for wider bridges, and continually incorporated the latest engineering wisdom and detailing.[47]

In the first three and one half years of work, the SHC designed over 1,500 bridges of all types. All were designed to carry a live load of 15 tons. Believing firmly in the use of reinforced concrete to "the fullest extent practical," the SHC was pleased that all but three of their designs had concrete floors. These figures include almost 900 bridges requested by local governments in 70 counties. Practically all the local bridges in the state during these years were either designed by the SHC or were based on SHC standard plans.[48]

Despite its enthusiastic support for concrete construction, the SHC declared in 1926 that the steel bridge "is not looked upon with disfavor," and it continued to refine its truss designs. In the late 1930's, it made a major commitment to keep its standardized plans up to date by dropping the Pratt truss design in favor of the Warren all overhead truss configurations. Newly-completed SHC-designed truss bridges, both monumental and modest, also continued to be featured in the photographic sections of the agency's biennial reports. Nevertheless, the SHC clearly favored concrete spans, citing advantages of lower cost, greater compatibility with aesthetic treatment, and greater adaptability to remodelling, especially in terms of roadway widening.[49] The metal truss, however, remained cost effective in many situations, and the SHC continued to design some truss bridges until well after World War II.

During its early years, the SHC was guided by five key figures, all of whom had previously worked at the Highway Division of the Geological Survey. These staff members were W.O. Hotchkiss, first chief of the Highway Division; Arthur R. Hirst, first State Highway Engineer; Martin W. Torkelson, first State Bridge Engineer; Herbert C. Kuelling, assistant highway engineer; and Walter C. Buetow, assistant bridge engineer. When these men moved on to the SHC, they found a helpful ally in Frederick E. Turneaure. Turneaure was Dean of the College of Engineering at the University of Wisconsin and had been instrumental in establishing the new state highway agency.[50]

Endnotes

1.The Gifford photograph album shows horse and human power being used on such projects. Wisconsin Department of Transportation records list 40 of the state's 125 Pratt half-hip pony trusses as being built in 1915 or later. Research on some of them indicates that it is likely that for most of these bridges, either the date of construction was wrongly guessed at or the bridges were moved to their current site after 1915 and the date listed in the files as being the date of the date of construction is actually the date of the move.

2. A.R. Hirst, "Bridges and Culverts for County Roads," Engineering News (October 9, 1913, p. 729. with minor modifications, these standards are reiterated in Wisconsin Highway Commission, Second Biennial Report, p.24)

3.For a more detailed history of the White River Bridge in Burlington Wisconsin, refer to Diane Kromm "White River Bridge" Historic American Engineering Record. HAER No. WI-21, unpublished 1987.

4. A builders plate is mounted on the southwest endpost and identifies Gifford's role in the project. A second plate mentioning the supervisors is mounted on the northeast endpost. The Armenia Town Supervisors identified were, Ole Norsby, Al Gorman, and George A. Mayhue. The Juneau County Supervisors were E.P. Rogers and George H. Livernash.

5.Wisconsin State Gazetteer and Business Directory, R.L. Polk & Co., Chicago, 1901-10, p. 1192; 1913-14, p. 1013; 1919-20, p. 1137. No listings for Sprague in Juneau County were found for 1901 to 1906. The volume for 1907-08 was not located. Wisconsin Blue Book, 1911, Madison, pp. 71,101. It is interesting to note that the town of Armenia's population declined during this period, from 837 in 1905 to 714 in 1910. This decrease is also reflected in the overall figures for Juneau County during this period.

6.Mss. Census, 1900, Enumeration District 47, sheet 1, line 62; Mss. Census, 1910, Enumeration District 64, sheet 6, line 94. Interview with Willis E. Gifford Jr. - Robert S. Newbery, October 5, 1987. Before moving to Michigan, Gifford married Elbertine Swan.

7.G.R. Angell & Company, Madison City Directory, Vol. 14, 1916, pp. 184, 627; Madison Directory Company, Madison City Directory, 1916, p. 301; Madison City Directory, 1931, p. 326.

8.Interview with Willis E. Gifford, Jr. - Robert S. Newbery, October 1987.

9.Historic American Engineering report WI-58, The Ferndale Road Bridge. This Pratt overhead bridge was also built by Gifford and Elkhart Bridge and Iron Company in 1910.

10.Gifford photo album.

11.Gifford's son could not remember the exact year but calculated it would have been shortly after World War II.

12.James L. Cooper, Iron Monuments to Distant Posterity, Indiana's Metal Bridges, 1870-1930, DePauw University, 1987, pp. 22-32. Curiously, Elkhart Bridge and Iron is not mentioned in either Anthony Deahl, ed., A Twentieth Century History & Biographical Record of Elkhart County, Indiana, New York, 1905, pp.235-42; or in Abraham E. Weaver, ed., A Standard History of Elkhart County, Indiana, Vol. 1 New York, 1916, pp. 268-75.

13.Cooper, Iron Monuments, pp. 29-30; Frederick L. Quivik, Historic Bridges in Montana, Historic American Engineering Record, National Park Service, U.S. Department of the Interior, Spring 1982.

14.Cooper, Iron Monuments, pp.29-30. The template method is assumed to be a more modern fabrication technique. Charles Evan Fowler, "Machinery in Bridge Erection," Cassier's Magazine, Vol. XVII, No. 4 (February 1900), pp.327-9. See also, Robert S. Newbery, Jeffrey A. Hess, and Robert F. Frame, III, Truss Bridges, Vol. II, Historic Bridges in Wisconsin, Wisconsin Department of Transportation, to be published in 1988.

15.Cooper, Iron Monuments, pp. 29-30.

16.Clayton Fraser, Historic Bridges of Colorado, eds., Rebecca Herbst and Vicki Rottman, Colorado Department of Highways,1986, p. 11.

17.Barbara Wyatt, Proj. Dir.,"Iron and Steel Truss Highway Bridges", Cultural Resource Management in Wisconsin: Vol. 2, The State Historical Society of Wisconsin. (June 1986), pp.12-1, 12-29. This report summarizes the findings of the state Historic Bridge Advisory Commission's (HBAC) study of truss bridges in Wisconsin including their ranking scale and listing of eligible structures.

18. Johnson, Bryan and Turneaure, Modern Framed Structures, p. 3. In other words, the "assemblage had rigidity and behaved as a unit." Ellis l. Armstrong, History of Public Works in the United States, 1776-1976, American Public Works Association, 1976, p. 109.

19. Milo S. Ketchum, Design of Highway Bridges, p.1

20. A rectangle, on the other hand, can become a parallelogram as everyone with a sagging screen door knows. The common solution to the sagging door is to run a small rod diagonally across it, thus creating two triangles. The resulting figure looks remarkably like one panel of a 19th century Pratt truss

21. American Association for State and Local History Technical Leaflet 95, History News, Vol. 32, No. 5, May 1977: T. Allan Comp and Donald Jackson, "Bridge Truss Types: A Guide to Dating and Identifying," 5, 6-7. Ketchum, Design of Highway Bridges, pp. 5-11.

22. James A. L. Waddell, Bridge Engineering, New York, 1925, p.16.

23. Theodore Cooper, "The Use of Steel for Bridges", American Society of Civil Engineers, Transactions, Vol. VIII (October, 1879), p. 265. Important railroad bridges in the United States were built of cast iron in the 1870's and thousands of short span cast iron girder bridges were still in use on the railroads in England and Wales as late as 1896. Waddell, Bridge Engineering, pp. 17, 24; Tyrrell, History of Bridge Engineering, p. 151.

24. Captain William E. Merrill, Iron Truss Bridges for Railroads, New York, 1870, p. 126.

25. Bessemer's initial claims of tons rather than pounds was met with scepticism but, after some initial disappointments, proved true. Douglas A. Fisher, The Epic of Steel, New York, 1963, p. 117.

26. David Plowden, Bridges: The Spans of North America, New York, 1974, pp.125-7; Fisher, Epic of Steel, p.103; Herbert W. Ferris, editor, Rolled Shapes: Historical Record - Dimensions and Properties - Steel and Wrought Iron Beams and Columns, American Institute of Steel Construction, New York, 1953.

27. A number of companies, including Wisconsin Bridge and Iron, continued to advertise both iron and steel bridges until the end of the century. See the advertisements for Wisconsin Bridge and Iron Company, in Polk's Wisconsin State Gazetteer and Business Directory, 1895-96, p. 687, and Wrought Iron Bridge Company in Cassier's Magazine, Vol. 17, No. 6, (April 1900). p. 25. On the page opposite the Wrought Iron advertisement, the Berlin Iron

Bridge Company prominently advertised only "Steel Bridges and Buildings"

28.Waddell, Bridge Engineering, Chapter IV, "Alloy Steels"; Economics of Bridgework; A Sequel to Bridge Engineering, New York, 1921, Chapter V, "Economics of Alloy Steel".

29.Leslie Aitchison, Engineering Steels, New York, 1921, p. vii; W.E. Dalby Strength and Structure of Steel and Other Metals, London, 1923, Relies on three sophisticated laboratory instruments designed and developed by the author. A brief overview of 20th century structural steels is in Edwin H. Gaylord and Charles N. Gaylord, Design of Steel Structures, New York, 1957, pp. 43-46.

30.Although the Biennial Reports were not sophisticated in their engineering discussions, they did highlight new techniques and designs. The lack of any mention of metallurgy in the Biennial Reports is taken as a measure of a lack of priority.

31.Hans Nelson Brue, "The Development of Highway Bridges In Wisconsin," Bachelors Thesis in Civil Engineering, University of Wisconsin, 1916, pp.4-5. The historical record is sketchy here, and there is no reliable census of bridges by type for this period. The 1880's and 1890's saw a large number of metal trusses built, often with some controversy of the higher first cost when compared to the familiar old wooden bridge. It was not just a Phenomenon of the late 19th century. Simple wood beam, beam-and -pier, and truss bridges were recommended for the cost-conscious land owner in Frederick S. Langa's, "Bridge Your Way to a Low Cost Lot", Rodale's New Shelter, April 1981, pp.66-75.

32.Diane Kromm, "Milford Bridge," Historic American Engineering Record Report, unpublished, 1987, HAER No. WI-21.

33.Oconomowoc City Clerk Records, 1871, City Engineer's Office, unprocessed collection, Archives Division, SHSW; Kromm, "Milford Bridge," pp.2-4.

34.T. Allan Comp and Donald Jackson, "Bridge Truss Types: A Guide to Dating and Identifying," American Association for State and Local History, Technical Leaflet 95, History News, 32 (May 1977); Working Files, HBAC.

35.Comp and Jackson, "Bridge Truss Types."

36.James A.L. Waddell, Economics of Bridge Work; A Sequel to Bridge Engineering, New York, 1921, pp. 73-74; Boller, Practical Treatise on the Construction of Iron Highway Bridges, pp. 44-49; "Discussion of American Railroad Bridges," American Society of Civil Engineers, Transactions 26 (No. 429, December 1889), p. 593. According to Boller (p. 47), "Whatever objection has been urged against shop-riveting is intensified in a high degree when the field-riveter steps in to do his part of the work."

37.Waddell, Economics of Bridgework, p. 7; "The Development of Bridge Trusses," Engineering Record, 42 (November 3, 1900) p. 411.

38.Fowler, "Some American Bridge Shop Methods, Machinery in Bridge Erection," Cassier's Magazine, 17 (January, February 1900), pp.200-215, 327-344; "Pneumatic Percussion Riveters," Engineering News 38 (March 3, 1898) pp.148-9; "Field Riveting by Power," Engineering News, 42 (October 27, 1900) p. 385; "Pneumatic Field Riveting in Railway Bridgework," Engineering News, 42 (October 27,1900) pp. 393-4.

39.Waddell, Economics of Bridgework, p. 74; "Development of Bridge Trusses," p. 411.

40.See, for example, the photograph of "a riveted steel (Pratt pony truss) highway bridge 40' span... built under supervision of the Highway Division" in Arthur H. Hirst and M.W. Torkelson, Culverts and Bridges (Madison, Highway Division, Wisconsin Geological and Natural History Survey, Road Pamphlet No. 4, second edition, 1908), p. 43. The SHC standard plan (dated 1908) for a riveted Warren pony truss with a 40 foot span is found in Microfilm reel M-1, "Miscellaneous Standards," Bridge Section, Wisconsin Department of Transportation.

41.A.R. Hirst, "Bridges and Culverts for County Roads," Engineering News (October 9, 1913, p. 729. With minor modifications, these standards are reiterated in Wisconsin Highway Commission, Second Biennial Report, p. 24.

42.U.S. Department of Transportation, Federal Highway Administration, "Design and Construction of Welded Bridge Members and Connections," Washington D.C., 1980, pp. 1, 6-9.

43.Ballard Campbell, "The Good Roads Movement in Wisconsin, 1890-1911," Wisconsin Magazine of History, No. 49 (summer 1966), pp. 273-93; M.C. Davis, A History of Wisconsin Highway Development, 1825-1945 (Madison, 1947), pp.218-22; Wisconsin Statutes, Second Session of the Legislature, January 10, 1849 (Southport, 1849), pp.182-83; Town Laws of Wisconsin, 1858, p.157; Legislature of Wisconsin, Private and Local Laws, 1867, pp. 60-61, 179-82; Laws of Wisconsin, 1881, Chapter 315, pp. 407-08; Laws of Wisconsin, 1885, Chapter 187, pp. 162-64. Richard N. Current, The History of

Wisconsin, Vol. II, The Civil War Era, 1848-1873, (Madison, 1976), p. 28; Robert Nesbit, Wisconsin, A History (Madison, 1973), p. 197. A sampling of available County Board records suggest that county-aid bridge projects were infrequent during the 1880's, and numbered five to ten per county, per year during the 1890's.

44.Campbell, "Good Roads," pp. 278-79; Laws of Wisconsin, 1907 (Madison, 1907), Chapter 552, p. 292.

45.Campbell, "Good Roads," pp. 279-84; Davis, Wisconsin Highway Development, p. 104.

46.State Highway Commission, Second Biennial Report, July 1, 1911 to January 1, 1915 (Madison, 1915), p. 24.

47.A review of Wisconsin Department of Transportation records, Bridge Section, Microfilm reel M-1.

48.Davis, Wisconsin Highway Development, pp. 112-13; SHC Second Biennial Report, pp. 21, 14, 30; see also SHC, Preliminary Biennial Report, July 1, 1911 to January 1, 1913 (Madison, 1913), p. 17.

49.The SHC succinctly assessed the pros and cons of steel truss and concrete bridges in its Sixth Biennial Report, 1925-1926 (Madison, 1926), p. 67. From 1911 to 1915, truss bridges in Wisconsin cost considerably less per foot than concrete structures. After 1915, steel began its "great advance in price." See SHC, Fourth Biennial Report, 1916-1918 (Madison, 1918), pp. 11-12; see also the comparative cost chart in Engineering News, no. 47 (February 28, 1917).

50.A brief biography of these men can be found in Robert S. Newbery, Jeffery A. Hess, and Robert F. Frame, III, Truss Bridges; Vol. II, Historic Highway Bridges of Wisconsin, Wisconsin Department of Transportation, (Madison, Forthcoming 1988).

Photocopy of historic photograph. View of bridge deck shortly after construction, looking east. From the photographic album of W. E. Gifford Sr. Photographer unknown (original print in possession of Robert Newbery, Historian, Wisconsin Department of Transportation, Madison Wisconsin).